SPAWNING TIMES AND LOCATIONS OF SPOTTED SEATROUT IN THE CHARLESTON HARBOR ESTUARINE SYSTEM FROM ACOUSTIC SURVEYS

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INTRODUCTION

Fishermen, naturalists, and scientists have long been aware that certain species of fish produce sound. Some of these sounds are the result of feeding or movements, but many fish produce sounds with specialized anatomical structures (Tavolga, 1980). It is generally recognized that these latter types of sounds are used for communication. In an environment where visibility is often reduced, sound carries much further than light and may be of greater importance for communication. Sounds created by fish may function to identify, warn, or attract other individuals Mok and Gilmore, 1983)

Many species in the family Sciaenidae have specialized muscles that attach to the swimbladder. Contractions of these muscles create vibrations in the swimbladder which move through the fish into its external environment as sound waves. Depending on the characteristics of these vibrations and ambient conditions, these sounds can be detected (with appropriate equipment) for 0.4 to 0.8 km (0.25-0.5 miles) away from the source (Fish and Mowbray, 1970). Lower frequency sounds propagate over a longer distance than higher frequencies which attenuate rapidly (Fish and Mowbray, 1970; Tavolga, 1980).

Sciaenids have been shown to aggregate in large spawning groups in the Gulf of Mexico (Wilson, 1989). Formation of these groups may depend both on sounds created by individuals to attract others of the same species as well as appropriate physical characteristics of an area. Fisheries biologists have used information gathered by passive and active sonic gear to estimate numbers, location, movements, and spawning states of targeted (Saucier, 1991; Saucier et al., 1992). Passive gear types, such as hydrophones, allow for non-destructive sampling of soniferous fish species. Estimates of total numbers of fishes, locations, frequencies, and durations of spawning events can be suggested. This information is critical to biologists in estimating the size of spawning populations.

The spotted sea trout, *Cynoscion nebulosus*, is an estuarine sciaenid that spawns from mid-May to late-August in South Carolina waters (Wenner et al., 1990). Saucier (1991), working in Louisiana, found spawning aggregations of sea trout using a hydrophone which was able to detect sounds produced by male spotted sea trout. Validation of spawning was attempted by sampling with a neuston net for newly fertilized sea trout eggs. Spawning aggregations were found in 10-15m deep, high current areas, and were often associated with structure on the bottom.

Preliminary sampling in the Charleston Harbor Estuary (CHE) during 1990 - 1992 also indicated that sea trout form aggregations during the spawning season. Using a hydrophone, these aggregations have been located near Ft. Johnson and on the west side of the main shipping channel under the Cooper River bridges. Sampling during 1992 indicated another aggregation near the mouth of the harbor. These aggregations were first observed during May, and subsequent irregular sampling showed that activity occurred through September. No sea trout sounds were heard during occasional sampling during late fall, winter and early spring. Life history work on sea trout in the Charleston area (Wenner et al., 1990) indicated that sea trout begin spawning in early-mid May and continue through mid-September, concurrent with sea trout sound production detected using the hydrophone.

Diurnal changes in sound production were evident from three 48 hour sampling periods, during the spring of 1992 and 1993. Sound production occurred over an approximately six hour period beginning about 1600hrs. Gill net sampling (pers. ob.) seems to indicate that the aggregations dispersed as sound production stopped.

No information is currently available concerning the number of spawning aggregations within the CHE system. Efforts described within attempt to identify the extent of spawning aggregations in the CHE and its surrounding waterways using sound production as a measure. Also attempted was verification of spawning activity through the capture of newly spawned eggs.

MATERIALS AND METHODS

Four transects were established to identify the extent of sea trout sound production within the Charleston Harbor estuarine system (Figure 1). These included the Ashley River (AR), the Wando River (WR), the Intracoastal Waterway (AIW) between Charleston Harbor and Capers inlet, and the Stono River (SR). The AIW, WR, and AR all had one end point in the mouth of Charleston Harbor, while the Stono River transect had its seaward point in the Stono Inlet. All transects were 20 - 30 km (13-15 nautical miles) in length and followed the navigable channels. Each transect was sampled twice per month, once during every two week period. The sampling order of the transects was chosen randomly within each two week period, with no transect done consecutively between periods.

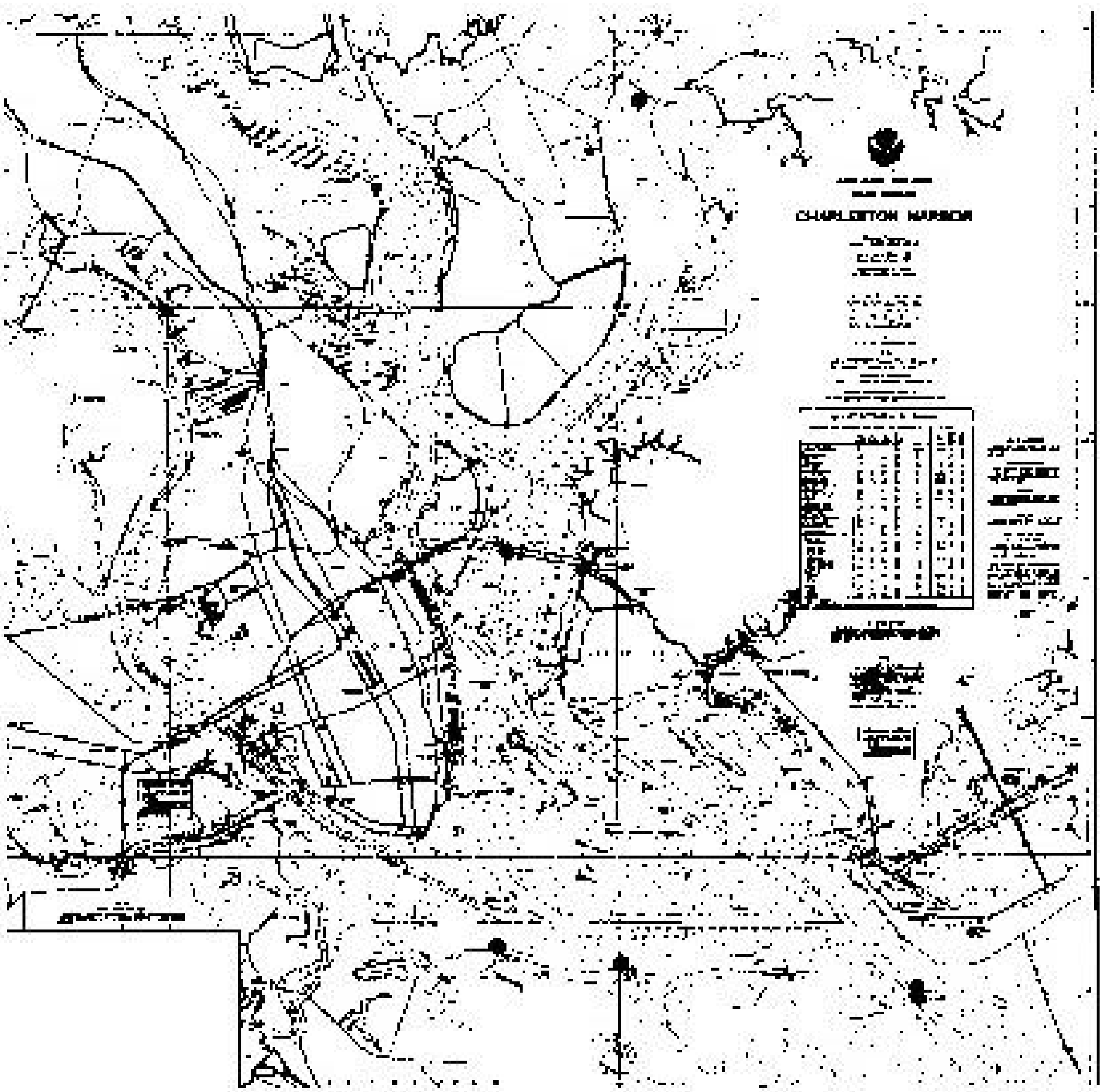

Figure 1. A chart of the Charleston Harbor showing site locations of greatest spotted seatrout sound production (May through August).

Figure 1. Map of the Charleston Harbor Estuary showing areas where transects were made. Stars indicate areas of intense sound production, all within the Charleston Harbor proper. Triangles indicate areas in which plankton tows were made.

Each transect was divided into 0.4 km sections, resulting in approximately 50-60 stations. A minimum of fifteen stations were sampled during a given sampling evening. Sampling stations along each transect were chosen by two methods:

1) Ten stations were randomly chosen, without replacement, from the pool of stations (when all stations were sampled once, selection of stations started over again). 2) Five additional stations were chosen based on characteristics believed important to the formation of spawning aggregations, or locations shown to be of interest during the course of the survey.

Transects occurred between 1600 and 2300 hrs, and were timed so that the aggregation at Ft Johnson was sampled at the beginning and end of each transect for verification of sound production occurring throughout the period. Stations were sampled from a 6 meter outboard with an Interocean hydrophone (Model 902). Surface and bottom temperatures and salinities were taken at the ends of each transect. Measurements were made with a stem thermometer and a Reichert optical refractometer.

Assumptions of sampling design:

1) Sampling was limited to the identification of aggregations based on recognition of characteristic sounds produced by spotted sea trout. The hydrophone used to sample sounds did not allow for verification of spawning, only the identification of aggregations.

2) In effort to reduce overall time, sampling was restricted to the deeper parts of the transects. Previous sampling indicated that aggregations associated with deeper water and high currents.

3) Sound intensity was independent of the distance to the sound source. While this assumption is obviously false, the time required to find the greatest sound intensity for each station would preclude finishing the transect before noise production stopped for the night. Occasional transects from bank to bank, perpendicular to the transect line, indicated that the highest noise intensity generally occurred in the channel.

Spawning Aggregation Verification

An experimental design was established to evaluate spawning activities in areas not previously considered conducive to formation of spotted sea trout spawning aggregations. Plankton samples were taken during suspected diurnal spotted sea trout spawning hours (1800-2100 hrs). The tidal state chosen (late ebb) assumed that any eggs spawned and fertilized the previous day could be readily identified and distinguished from hours-old eggs. Only eggs spawned at or near the specified site should have been collected, unless they were the result of contamination from an upcurrent spawning location. Plankton tows using a neuston net (0.5 meter circular 505 micron net with a 333 micron cod-end) were made in each of four locations during the last 1.5 hours of ebbing tide on 27 May, and 10 June, 1993 (Table 1). These locations were: 1) down-current of the spawning activity at Ft. Johnson in lower Charleston Harbor (Figure1), 2) immediately upcurrent of the Ft. Johnson site, 3) the Ashley River approximately 1 kilometer (km) down-current of the most up-river point where sea trout aggregations were heard, 4) a site in the Ashley River above which no spawning sounds were detected. This farthest up-river site was used as the control site. The upriver position and late ebbing tide was

Table 1. Results of plankton tows in the Ashley River/Charleston Harbor conducted in May and June, 1993. Ashley AR50 = farthest up-river sampling location (up-river beyond upper limit of trout sound production). Ashley AR45 = site downriver of uppermost trout noise identification.

27 May 1993

Location	Eggs found	Species	Noise
Fort Johnson Down stream[1]	Early eggs	Trout	many trout
Fort Johnson Up stream	Early eggs	Trout?	some trout
Ashley AR-50	no eggs	-	no trout
Ashley AR-45	one egg	sciaenid	some trout

10 June 1993

Location	Eggs found	Species	Noise
Fort Johnson Down stream	early eggs (2)	sciaenid	many trout & Black Drum
Fort Johnson Up stream	no eggs	-	no trout
Ashely AR-50	no eggs	-	no trout
Ashley AR-45	eggs (56)	sciaenid	many trout

[1]Indicates position relative to peak sound intensity

expected to preclude any recently spawned sea trout eggs. This was based on the assumption that active sea trout spawning occurs in locations of noise production.

Three tows were made at each site. Eggs and larvae from each tow were collected and pooled within a site. Eggs identified as belonging to members of the family sciaenidae were initially separated into species groups based on overall diameter. Live eggs and larvae were placed into aerated containers, one container per site. Eggs were allowed to hatch, and specific identifications were attempted from examination of late yolk-sac larvae. A manuscript key by Holt and Holt (1989) was used for specific identification of newly hatched sciaenid larvae.

RESULTS

Transects were started on March 15, 1993 and continued through September 30, 1993. Each transect was conducted 12-14 times over this period. Sea trout activity was first heard in the upper region of the Wando river on April 27, 1993. Activity was detected on all other transects after that date, and continued until the end of September. Initially, sea trout noise production had the highest intensities (120-130 Db) in the upper areas of the rivers (except the AIW transect) with sonic activity beginning around 1600-1700 hrs. Activity was heard primarily in 3-15 meter deep channels with either no or low activity in shallow water areas (less than 3 meters). A few individuals were heard in shallow water in the very broad areas of the Wando River.

High intensity (>140 Db) sound production was generally associated with bottom structure and high current. The northern tip of Ft Johnson, the west side of the shipping channel under the Cooper River bridge, the end of the James Island Yacht Club (JIYC) pier, and the Stono River Bridge, had consistently higher intensities (142-145 DB).

Salinities and temperatures were measured at the surface and bottom at each end of a transect (Table 2). The Ashley River had the greatest freshwater input which resulted in the strongest salinity gradient. This was the only transect in which there was an upper limit to the distribution of sea trout sound production.

Sciaenid eggs were easily separated from those of other families commonly taken in the plankton tows, which included engraulids, and gobiids. Other species known to be spawning during the time sampled had differently sized eggs: *Bairdiella chrysura* 0.70-0.82 mm, *Cynoscion nebulosus* 0.80-0.90 mm, *C*. *regalis* 0.75-0.85 mm, *Mentichirrus americanus* 0.72-0.85, and *Pogonias cromis* 0.95-1.10 mm (Daniel, 1994).

No eggs or larvae were found in neuston net samples taken from the farthest upriver station (Table 1). Only one sciaenid egg was taken in late May from 1km down-current of the highest up-river station where fish sounds were detected. However, many newly spawned sciaenid eggs were captured at this location in early June. A few of these new eggs hatched into larvae, which were tentatively identified as spotted seatrout. However, confusion persists in adequately separating eggs and early larvae of this species from the concurrently spawning southern kingfish (*Mentichirrus americanus*).

TABLE 2. Temperature and salinity values taken during this study in the Charleston Harbor Estuarine System. Ranges are shown of data taken at the beginning and end of each transect event. S= surface measurements, B= bottom measurements; T^o= temperature in ^{o}Celcius, $^o/_{oo}$= salinity in parts per thousand. ICW=Itracoastal Water Way.

		Upper end		Lower end	
Transect location		S	B	S	B
Ashley River	T^o	18-30	17-30	16-30	15-28
	$^o/_{oo}$	0-18	4-19	26-28	29-30
Wando River	T^o	16-28	16-27	14-28	14-27
	$^o/_{oo}$	10-18	10-18	15-28	19-28
Stono River	T^o	20-29	20-29	17-28	16-28
	$^o/_{oo}$	9-27	9-27	27-32	28-32
ICW	T^o	18-27	18-26	17-28	16-26
	$^o/_{oo}$	28-32	28-32	22-28	28-30

Both areas sampled near Ft. Johnson contained eggs and larvae of sciaenids. Many recently spawned sciaenid eggs were captured near Ft. Johnson in late May, but few in early June. Species of larger larval specimens (4-8mm standard length) sampled in early June near Ft. Johnson included the sciaenids *Stellifer lanceolatus*, *Bairdiella chrysura*, and *Mentichirrus* sp.; the gobiid *Gobiosoma bosci*; and the engraulid *Anchoa mitchilli*. No larvae *of Cynoscion nebulosus* or *C. regalis* were taken, even though these were probably available for capture during this time.

DISCUSSION

Hydrophone sampling for sea trout, red drum, and black drum has been done by our lab intermittently for the last 2-3 years. Sampling has been limited to sporadic attempts to find aggregations of these species with no attempt to monitor aggregations over a spawning season. This study monitored *Cynoscion nebulosus* aggregations throughout the 1993 spawning period. Based on prior sampling, we expected to find aggregations in habitats with characteristics similar to those locations where aggregations had previously been found. The two known locations were at the mouth of the Ft Johnson boat slip on the property of SCDNR, and the west side of the main shipping channel under the Cooper River bridges. These two sites have high currents, and 6-13 meters of water depth. Larger, noisier aggregations were found under many of the bridges on the transects during the course of sampling. These sites included the Stono River bridge, the Mark Clark bridge on the Wando River, and the Ben Sawyer bridge over the Intra-coastal waterway. The sound intensity of these aggregations generally peaked (140-145 decibels) between 1900 and 2200 hrs.

We also heard aggregations in the middle of many of the channels during the course of the transects. These aggregations seemed more diffuse, peak sound

Intensity was generally lower (110-125 decibels) than previously known locations. Drifts from 0.4 - 0.8 km along the channel found no large (<10 Db) fluctuations in sound intensity. Generally, the intensity of the sound at these channel aggregations were 15-20 decibels lower than the larger aggregations at the locations mentioned above.

Sounds produced by spotted sea trout which have been interpreted as indicating spawning aggregations were heard throughout the Charleston Harbor Estuary. It is unclear at this point whether this indicates spawning in all areas or if some sound production occurs in non-spawning locations, i.e. along the channels. Previous workers have only reported aggregations at single locations, not spread over the channel bottom as indicated here. Some verification work has been done for the aggregations at Ft Johnson and the JIYC. This included plankton tows for early egg stages and net sets for spawning adults. This limited work helped support the idea that sea trout are spawning in these places. These areas are similar to those identified as spawning areas in Louisiana (Saucier, 1991). Neuston net tows in channels, away from suspected spawning areas were inconclusive, did not verify or refute spawning in the channel aggregations. It is unknown at this point whether spawning is limited to the large aggregations associated specifically with structure and high current.

Initial sampling showed sea trout begin making noise at approximately 1600 hours. However, as the season progressed, the daily onset of noise production progressively moved to later in the day. During July, noise production generally did not start until 1900 hours.

A seasonal geographic shift in the channel aggregations was also observed. Initially sounds were heard 6 - 10 km from the mouth of the harbor with no sea trout sound production in the harbor proper except at Ft Johnson and the Cooper River bridges. By July, sea trout sound had decreased in the upper 1-2 nm of the transects while sound intensity had increased in the harbor. Based on histological data (Wenner et al., 1990), the peak period of spawning is during May and June. It is possible that these animals spawn in many places initially with more restricted activity later in the season.

Preliminary Information on Black Drum and Red Drum

Transects were started before the black drum began spawning. Sonic activity was first heard on March 29, 1993. While individual black drum grunts were located in all areas surveyed, there was only one area where an aggregation of more than one or two animals were found. This area was in the mouth of Charleston harbor, in and around a 24 m hole. If animals form aggregations to spawn, then this site seems to be the only inshore spawning location in the areas sampled. Other inlets were sampled (Capers, Price's, Dewees, and Stono), as well as a 23 m hole inside of Dewees Inlet, did not have spawning aggregations. These fish may require larger inlets such as Port Royal and St Helena Sound.

Based on preliminary data, red drum seem also to form spawning aggregations. This species, however, does not make recognizable noises inside the estuary. The only location of identifiable red drum sounds were heard in the mouth of the Charleston harbor. Faint noises were heard on July 8, 1993, with intense sounds produced by July 27, 1993.

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